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SURFACE SOIL ANALYTICAL RESULTS FOR THE VICINITY PROPERTY 9 AREA

Weldon Spring Site Remedial Action Project
Weldon Spring, Missouri

JUNE 1994 **REV. 1**

U.S. Department of Energy
Oak Ridge Operations Office
Weldon Spring Site Remedial Action Project

Prepared by MK-Ferguson Company and Jacobs Engineering Group

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Weldon Spring Site Remedial Action Project

Surface Soil Analytical Results for the Vicinity Property 9 Area

Revision 1

June 1994

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U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office
Under Contract DE-AC05-86OR21548

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1 INTRODUCTION

1.1 Purpose

This report discusses the results from surface soil sampling in the area south of the quarry, including Vicinity Property-9 (VP). The sampling was performed by Weldon Spring Site Remedial Action Project (WSSRAP) personnel on January 11 and 12, 1994.

As shown on Figure 1-1, the study area was divided into 14 sample areas. Each area was 200 ft across and extended from the Katy Trail to the Femme Osage Slough. Nine random samples were taken and composited from each of the 14 areas. The intervals sampled were from the surface to 6 in. in depth.

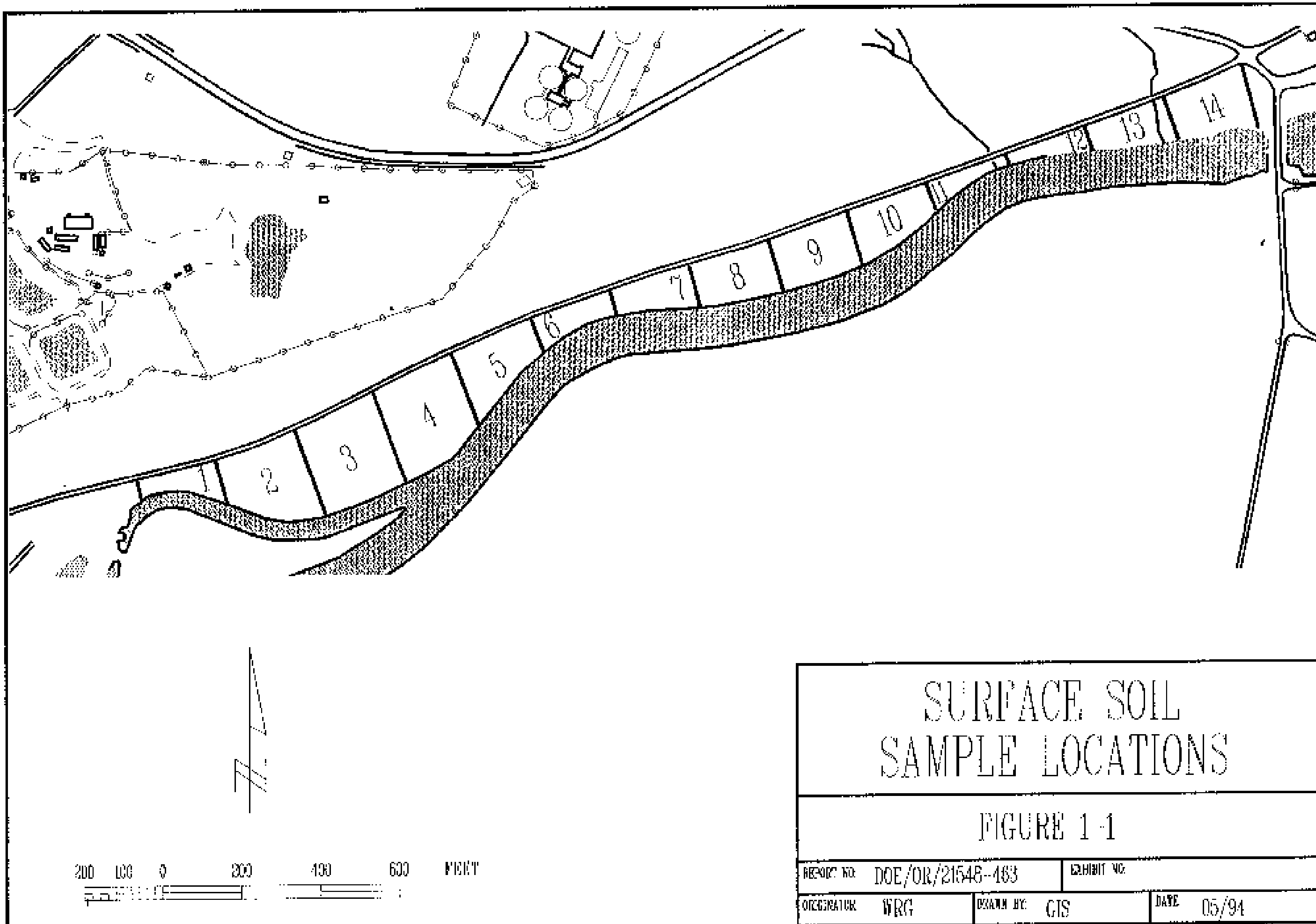
1.2 Scope of Work

This report provides the results of surface soil sampling which took place January 11 and 12, 1994, in the area south of the Katy Trail and north of the Femme Osage Slough near the Weldon Spring Quarry. This investigation is part of the Quarry Residuals Operable Unit (QROU) characterization and was performed as described in the *Quarry Residuals Sampling Plan* (Ref. 1).

1.3 Background

The Weldon Spring Quarry was used as a disposal area by the Army and the Atomic Energy Commission (AEC) in the 1940s, 50s and 60s for wastes contaminated with nitroaromatics, radionuclides, and other chemical contaminants. In 1987, the site was identified as requiring remediation according to the guidelines in the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and added to the National Priority List (NPL).

In 1990, a *Record of Decision* (ROD) (Ref. 2) was signed between the Environmental Protection Agency (EPA) and the Department of Energy (DOE) requiring the bulk wastes to be removed from the quarry and transported to the Weldon Spring Chemical Plant and stored there



SURFACE SOIL SAMPLE LOCATIONS

FIGURE 1-1

REPORT NO.	DOE/OR/21548-463			EXHIBIT NO.	
ORIGINATOR	WRG	DRAWN BY:	GIS	DATE	05/94

pending final disposal. At that time, it was determined that an additional *Remedial Investigation/ Feasibility Study* (RI/FS)-ROD for the Quarry Residuals Operable Unit would be required to determine the extent and threat of remaining contamination. Earlier characterization found contamination in the groundwater and soils south of the quarry.

A *Work Plan* (Ref. 3) and a *Sampling Plan* (Ref. 1) for the QROU were completed by the DOE and approved by EPA and the Missouri Department of Natural Resources (MDNR).

As part of the sampling plan, a surface soil sampling effort was scoped and described for the strip of land between the Katy Trail and the Femme Osage Slough south of the quarry. Although most of this area has been inundated by Missouri River flooding in 1993 and 1994, for a short time in early 1994 this area was dry enough to allow sampling. Because the MDNR had expressed concern for recreational users of the Katy Trail, the WSSRAP agreed to expedite sampling to the extent possible.

On January 11 and 12, 1994, WSSRAP personnel performed surface soil sampling. As shown in Figure 1-1, the area was divided into 14 sections, each 200 ft wide and extending from the Katy Trail to the Femme Osage Slough. Nine random samples were taken from the top 6 in. of the surface and composited for each of the 14 sections.

2 INVESTIGATION RESULTS

All samples were containerized, preserved, and shipped off site for laboratory analyses according to Weldon Spring Site Remedial Action Project (WSSRAP) procedures. Chemical analyses were performed by Weston Laboratory and radiological analyses were performed by Barringer Laboratory. No quality control problems were noted. Sample SO-194015 is a blind duplicate from Section 5.

2.1 Nitroaromatics

None of the following six nitroaromatics were detected in any of the samples: 1,3,5-Trinitrobenzene; 1,3-Dinitrobenzene; trinitrotoluene (TNT); 2,4-Dinitrotoluene (DNT); 2,6-DNT; and nitrobenzene. The highest detection limit for any of the individual compounds was 2.50 μg/g. Results are shown in Table 2-1.

2.2 Metals

Cadmium (with a maximum detection limit [DL] = 1.3 μg/g), mercury (DL = 0.08 μg/g) and silver (DL = 1.7 μg/g) were nondetects in all samples. Results are shown in Table 2-2. Arsenic values ranged from 4.9 μg/g to 8.3 μg/g, barium from 170 μg/g to 246 μg/g, chromium from 11 μg/g to 15.2 μg/g, and lead from 14.1 μg/g to 29.3 μg/g. Selenium had two detects, 0.64 μg/g and 0.77 μg/g, which are near the detection limit.

2.3 Radionuclides

Table 2-3 illustrates the results of radiological analysis.

TABLE 2-1 Surface Soil Nitroaromatic Results*

Location	Sample ID	1,3,5-Trinitrobenzene	1,3-Dinitrobenzene	2,4,6-TNT	2,4-DNT	2,6-DNT	Nitrobenzene
1	SO-194001	ND(2.50)	ND(0.630)	ND(2.50)	ND(0.630)	ND(0.630)	ND(0.630)
2	SO-194002	ND(2.40)	ND(0.600)	ND(2.40)	ND(0.600)	ND(0.600)	ND(0.600)
3	SO-194003	ND(2.40)	ND(0.590)	ND(2.40)	ND(0.590)	ND(0.590)	ND(0.590)
4	SO 194004	ND(2.50)	ND(0.630)	ND(2.50)	ND(0.630)	ND(0.630)	ND(0.630)
5	SO-194005	ND(2.40)	ND(0.600)	ND(2.40)	ND(0.600)	ND(0.600)	ND(0.600)
5	SO-194005-DU	ND(2.40)	ND(0.600)	ND(2.40)	ND(0.600)	ND(0.600)	ND(0.600)
5	SO-194015	ND(2.50)	ND(0.630)	ND(2.50)	ND(0.630)	ND(0.630)	ND(0.630)
6	SO-194006	ND(2.20)	ND(0.560)	ND(2.20)	ND(0.560)	ND(0.560)	ND(0.560)
7	SO-194007	ND(2.50)	ND(0.620)	ND(2.50)	ND(0.620)	ND(0.620)	ND(0.620)
8	SO-194008	ND(2.300)	ND(0.570)	ND(2.30)	ND(0.570)	ND(0.570)	ND(0.570)
9	SO-194009	ND(2.30)	ND(0.590)	ND(2.30)	ND(0.590)	ND(0.590)	ND(0.590)
10	SO-194010	ND(2.20)	ND(0.550)	ND(2.20)	ND(0.550)	ND(0.550)	ND(0.550)
11	SO-194011	ND(2.40)	ND(0.600)	ND(2.40)	ND(0.600)	ND(0.600)	ND(0.600)
12	SO-194012	ND(2.40)	ND(0.590)	ND(2.40)	ND(0.590)	ND(0.590)	ND(0.590)
13	SO-194013	ND(2.20)	ND(0.560)	ND(2.20)	ND(0.560)	ND(0.560)	ND(0.560)
14	SO-194014	ND(2.40)	ND(0.610)	ND(2.40)	ND(0.610)	ND(0.610)	ND(0.610)

TABLE 2-1 Surface Soil Nitroaromatic Results* (Continued)

Location	Sample ID	1,3,5-Trinitrobenzene	1,3-Dinitrobenzene	2,4,6-TNT	2,4-DNT	2,6-DNT	Nitrobenzene
	Chemical Plant ALARA	-		14	-	-	-
	1 X 10^{-6} Risk	-	-	2.8	0.13	0.13	

* All results are given in μg/g.
( ) indicates detection limit

TABLE 2-2 Surface Soil Metals Results*

Location	Sample ID	Sulfate [1]	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
1	SO-194001	340	5	192	ND(1.1)	12.7	16.7	ND(0.07)	ND(0.59)	ND(1.40)
2	SO-194002	496	4.9	170	ND(1.2)	11	15.7	ND(0.08)	ND(0.60)	ND(1.50)
3	SO-194003	1050	5.4	189	ND(1.2)	12.3	15.2	ND(0.08)	ND(0.63)	ND(1.50)
4	SO-194004	852	7.1	203	ND(1.3)	13.1	14.1	ND(0.08)	ND(0.63)	ND(1.60)
5	SO 194005	898	7.2	228	ND(1.3)	14.3	19.8	ND(0.08)	ND(0.67)	ND(1.70)
5	SO 194005 DU	870	6.7	225	ND(1.3)	14.5	14.5	ND(0.08)	0.77	ND(1.70)
5	SO-194015	872	5.9	217	ND(1.2)	13.5	15.6	ND(0.06)	ND(0.64)	ND(1.60)
6	SO-194006	596	7.4	209	ND(1.3)	13.1	29.3	ND(0.07)	ND(0.66)	ND(1.60)
7	SO-194007	619	5.7	195	ND(1.3)	13	17.5	ND(0.08)	ND(0.63)	ND(1.60)
8	SO-194008	427	6.3	193	ND(1.2)	12.9	18.9	ND(0.08)	ND(0.63)	ND(1.60)
9	SO-194009	356	6	192	ND(1.2)	13.3	17.1	ND(0.08)	ND(0.62)	ND(1.50)
10	SO-194010	550	6.8	186	ND(1.2)	11.7	15.4	ND(0.08)	0.64	ND(1.50)
11	SO-194011	564	6.1	208	ND(1.2)	13.6	17.9	ND(0.06)	ND(0.59)	ND(1.50)
12	SO-194012	400	6.6	196	ND(1.1)	13.4	16.2	ND(0.07)	ND(0.58)	ND(1.40)
13	SO-194013	421	6.2	182	ND(1.2)	11.9	16.8	ND(0.06)	ND(0.57)	ND(1.40)
14	SO 194014	448	8.3	246	ND(1.3)	15.2	21.6	ND(0.08)	ND(0.68)	ND(1.70)
	Mean	610	6.3	202	-	13	18		-	-
	Standard Deviation	219	0.9	19	-	1	4	-	-	-

TABLE 2-2 Surface Soil Metals Results* (Continued)

Location	Sample ID	Sulfate+	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
	Chemical Plant ALARA	-	45	-		90	240	-	-	-
	1×10^{6} Risk	-	14		270,000	40,000	-	-	-	-

* All results are given in $\mu g/g$.
+ Sulfates included in this table for convenience.
( ) Indicates Detection Limit

TABLE 2-3 Surface Soil Radiological Results*

Location	Sample ID	Gross α	Gross β	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium 232	Uranium (Total)
1	SO 194001	16	25	1.9	2.1	1.3	2.7	1.3	1.9
2	SO-194002	26	30	1.1	2.2	1.4	1.3	1.2	2.2
3	SO-194003	30	32	1.2	1.5	1.2	1.4	1.6	11
4	SO-194004	23	33	2.4	1.4	1.6	1.6	1.1	11
5	SO-194005	54	51	1.3	2.2	1.1	1.7	1	29
5	SO-194005-DU	56	47	1.2	2.1	1.3	1.9	1.7	31
5	SO-194015	60	58	0.7	1.4	1.2	1.5	0.4	47
6	SO-194006	25	32	1.8	1.8	1	2	1.2	2.4
7	SO-194007	15	30	1.4	1.5	1.4	1.7	1.3	2.2
8	SO-194008	19	30	1.7	2.7	1.6	1.4	1.7	1.8
9	SO 194009	23	31	0.5	2.1	1.2	1.8	1.6	1.9
10	SO-194010	19	28	1.5	1.5	2	2.2	1.1	1.6
11	SO-194011	26	29	1.3	1.8	1.8	1.3	1.1	2.2
12	SO-194012	18	26	1.9	1.3	1.1	1.8	0.7	2
13	SO-194013	8.9	32	2.1	2.3	1.5	1.5	1.4	1.8
14	SO 194014	19	31	1.5	1.7	1.6	1.6	1	1.7
	Mean	27	34	1.5	1.85	1.38	1.71	1.21	9.41
	Standard Deviation	14.93	9.18	0.48	0.39	0.25	0.35	0.34	13.41

TABLE 2-3 Surface Soil Radiological Results* (Continued)

Location	Sample ID	Gross α	Gross β	Radium-226	Radium-228	Thorium-228	Thorium-230	Thorium-232	Uranium (Total)
	Chemical Plant ALARA	-	-	5	5	-	5	5	30
	1 X 10^{-6} Risk	-	-	0.14	0.43	-	42	8	24**

* All results are given in pCi/g.
** This value is for Uranium-238, not Total Uranium

3 DISCUSSION

The following results from the surface soil sampling are compared to the cleanup-values contained in the *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (Ref. 4) and to risk values contained in Appendix A of the *Quarry Residuals Work Plan* (Ref. 3), as prepared by Argonne National Laboratory.

3.1 Nitroaromatics

Nitroaromatics were all nondetect. The detection limit for 2,4,6-Trinitrotoluene (TNT) was near the 1×10^{-6} risk; for the two Dinitrotoluene (DNT) species, the detection limit was approximately half of the 1×10^{-5} risk. The detection limit for TNT was well below the as low as reasonably achievable (ALARA) level derived for the chemical plant.

3.2 Metals

None of the three metals (arsenic, chromium, and lead) for which chemical plant surface ALARA goals have been derived were found in levels above or near their ALARA goals. Cadmium and chromium are several orders of magnitude below their 10^{-6} risk levels. A few of the arsenic values slightly exceed one-half the derived 10^{-6} risk level.

3.3 Radionuclides

Uranium results show an area of apparent contamination in Sample Area 5. The laboratory took a split from the original taken from Area 5, and both analyses indicated uranium at the 30 pCi/g ALARA goal. A duplicate sample taken from Area 5 exceeds the ALARA goal with a measured value of 47 pCi/g. All three lie well below the derived 1×10^{-5} risk level. Sample areas 3 and 4 also show elevated levels of uranium, but these are below 1×10^{-6} risk levels.

All thorium values are below chemical plant ALARA and an order of magnitude below the corresponding 1×10^{-6} risk values.

Based on the coefficient of variation and a skewness coefficient of < < 1 for the radium sample populations, the radium isotopes are normally distributed and represent natural background levels. There appears to be no correlation between the radium concentrations and uranium levels.

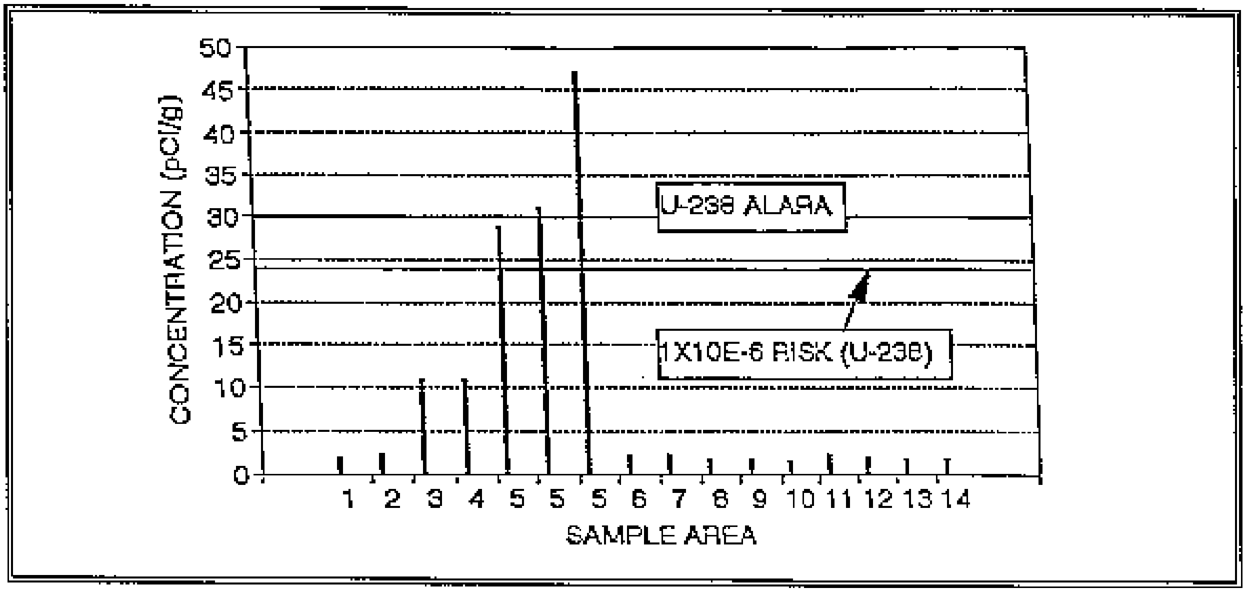


FIGURE 3-1 Total Uranium

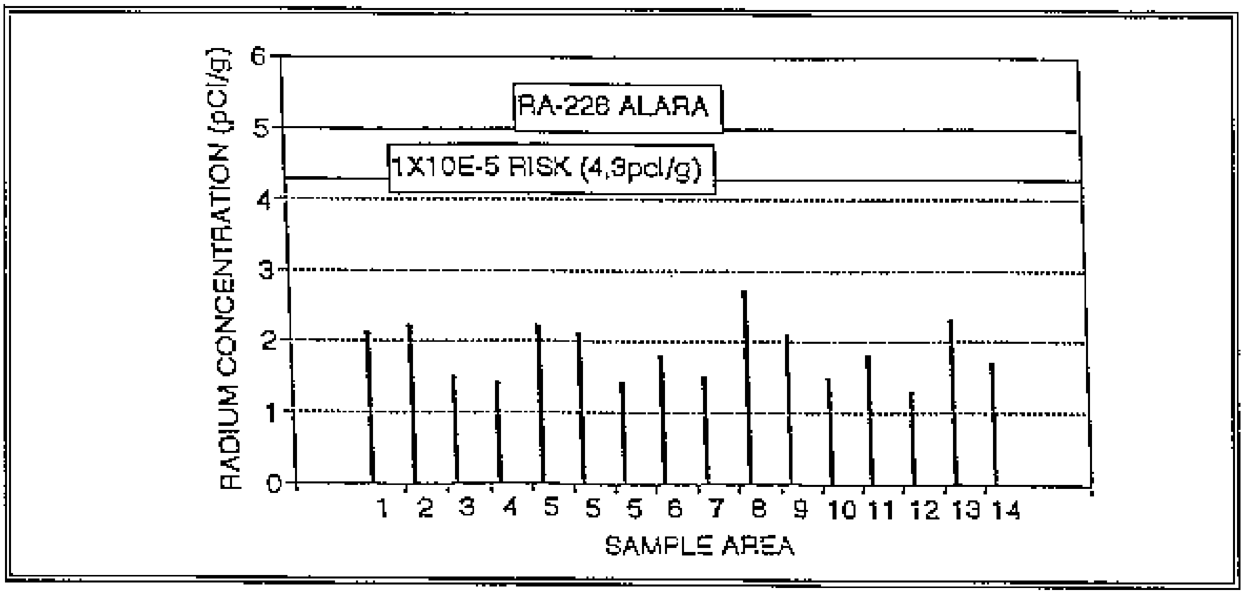


FIGURE 3-2 Radium 228

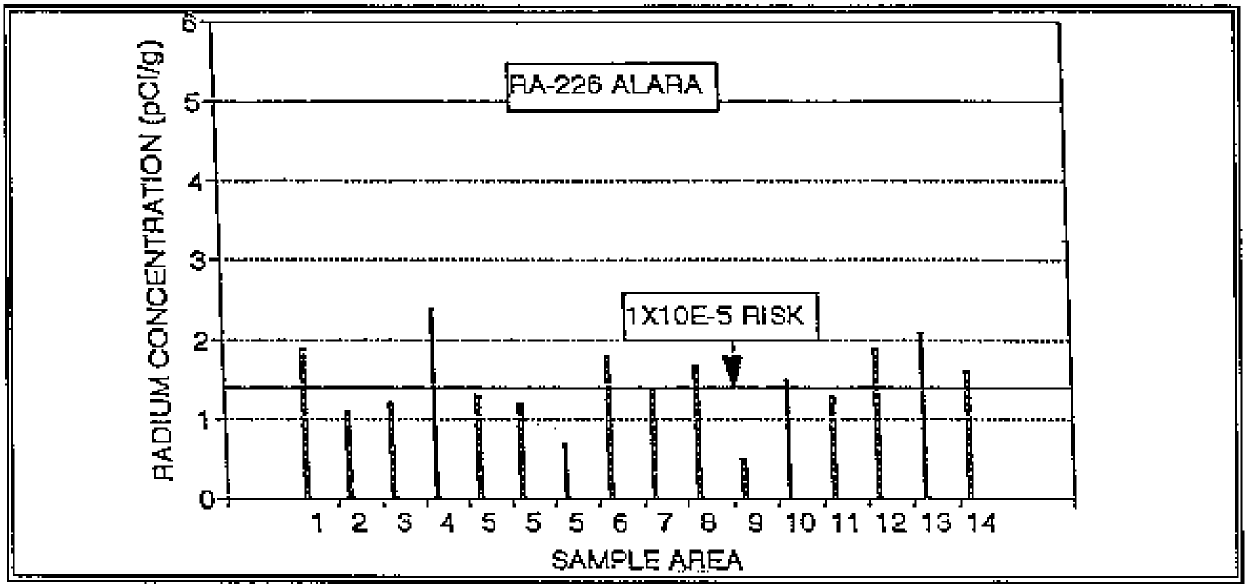


FIGURE 3-3 Radium 226

Table 3-1 is a summary of the results compared to the Argonne National Laboratory (ANL) risk estimates and the chemical plant surface ALARA levels.

TABLE 3-1 Comparison of Results to Standards

Parameter	# Samples Exceeding ALARA		# Samples Exceeding 10^{-6} Risk		# Samples Exceeding 10^{-5} Risk		# Samples Exceeding 10^{-4} Risk	
	#	Areas	#	Areas	#	Areas	#	Areas
Arsenic	0	-	0	-	0	-	0	-
Ra-226	0	-	16	All	9	1,4,6, 7,9, 10,12, 13,14	0	-
Ra-228	0	-	16	All	0	-	0	-
Uranium	2	5	3	5	0	-	0	-

4 CONCLUSIONS

These results are preliminary and will be fully evaluated as the Remedial Investigation/Feasibility Study (RI/FS) process is completed; but at this time, there appears to be no reason to be concerned with or to remediate the surface soils in this area.

Based on these results, some of the positions planned for the subsurface soil borings should be moved to better define the boundary of Vicinity Property-9, which corresponds to Sample Area 5 of this surface soil sampling.

5 REFERENCE

1. MK-Ferguson Company and Jacobs Engineering Group. *Quarry Residuals Sampling Plan*, Rev. 1. DOE/OR/21548-382. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. January 1994.§

2. Argonne National Laboratory. *Record of Decision for the Management of the Bulk Wastes at the Weldon Spring Quarry*, Rev. 0. DOE/OR/21548-317. St. Charles, MO. September 1990.§

3. Argonne National Laboratory. *Work Plan for the Remedial Investigation/ Feasibility Study-Environmental Assessment for the Quarry Residuals Operable Unit at the Weldon Spring Site.* DOE/OR/21548-243. Prepared for the U.S. Department of Energy, Weldon Spring Site Remedial Action Project by the Environmental Assessment Division. St. Charles, MO. January 1994§

4. U.S. Department of Energy. *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site.* DOE/OR/21548-376. Oak Ridge Field Office. St. Charles, MO. September 1993.§

APPENDIX A
Derivation of Risk-based Soil and Water Concentrations

(from the *Work Plan For The Remedial Investigation/Feasibility Study-Environmental Assessment For The Quarry Residuals Operable Unit At The Weldon Spring Site* DOE/OR/21548-243, dated November 1993)

APPENDIX:

DERIVATION OF RISK-BASED SOIL AND WATER CONCENTRATIONS

The calculated concentrations of radioactive and chemical contaminants in soil and groundwater that correspond to different levels of risk and hazard quotient are presented in this appendix. The contaminants considered are those identified in Section 3.1.2 as the preliminary contaminants for the quarry residuals area. The risk-based concentrations for those contaminants were derived on the basis of methods provided in *Risk Assessment Guidance for Superfund, Part B, Development of Risk-Based Preliminary Remediation Goals* (EPA 1991). These risk-based concentrations provide input to the data quality objectives planning process (Section 4.1) and are used to help develop the sampling plans for the quarry area. The results presented in this appendix are preliminary and will be revised in the future as the data quality objectives and sampling plans are further developed.

A.1 SOIL

A recreational visitor (or trespasser within the quarry proper) was identified as the most likely receptor to the quarry residuals area under current land use and under hypothetical future conditions (Section 3.1). For this receptor, exposure to surface soil would be due primarily to direct ingestion of and dermal contact with soil and to inhalation of radon and airborne particulates derived from soil. For radiological contaminants, external gamma irradiation would also be an exposure pathway. The risk-based soil concentrations are calculated by combining the appropriate intake and risk equations for these pathways, except for the dermal pathway. The dermal pathway is excluded because for most compounds the necessary parameters for calculating the risks associated with this pathway are not available.

Concentrations of radiological contaminants in soil corresponding to specified risk levels were calculated as follows:

$$R_{si} = \frac{TR}{A + B + C + D} \tag{A.1}$$

where:

$$A = \frac{6 \times 10^{-7}}{\text{mrem}} \times EF \times ED \times IR_s \times CF_1 \times DCF_{ing} \;;$$

$$B = \frac{6 \times 10^{-7}}{\text{mrem}} \times ET \times EF \times ED \times IR_a \times CF_2 \times \frac{1}{PEF} \times DCF_{inh} \;;$$

$$C = \frac{6 \times 10^{-7}}{\text{mrem}} \times ET \times EF \times ED \times DCF_{\gamma} \;; \text{ and}$$

$$D = 2.5 \times 10^{-6} \times ET \times EF \times ED \times IR_a \times \frac{3.5 \times 10^{-4}}{WLM}$$

(term D is only included for radium-226).

and:

TR = excess individual lifetime cancer risk (unitless);

R_{si} = soil concentration of radionuclide i (pCi/g);

IR_a = inhalation rate (m^3/h);

IR_s = soil ingestion rate (mg/event);

CF_1 = conversion factor (10^{-3} g/mg);

CF_2 = conversion factor (10^{-3} g/kg);

ET = exposure time (h/event);

EF = exposure frequency (events/yr or d/yr);

ED = exposure duration (yr);

PEF = particulate emission factor (4.63×10^9 m^3/kg [EPA 1991]),

DCF_{γ} = external gamma dose conversion factor for radionuclide i [(mrem/h)/(pCi/g)] (see Table 4.1 of the

- baseline assessment (BA) for the chemical plant area [DOE 1992]);

DCF_{ing} = ingestion dose conversion factor for radionuclide i (mrem/pCi) (see Table 4.1 of the BA for the chemical plant area);

DCF_{inh} = inhalation dose conversion factor for radionuclide i (mrem/pCi) (see Table 4.1 of the BA for the chemical plant area); and

WLM = working level month.

Term D is included in Equation A.1 to incorporate inhalation of radon-222 generated from radium-226 in soil. A comprehensive discussion of the radon pathway, including equations, is provided in Section 3 of the BA for the chemical plant area, and the risk factors used in Equation A.1 are discussed in Section 4.1.

For chemical contaminants, the concentrations corresponding to specified risk levels were calculated as follows:

$$C_{si} = \frac{TR \times BW \times AT \times CF_4}{(EF \times ED)\ [(SF_{oi} \times CF_3 \times IR_s) + (SF_{ii} \times IR_a \times ET \times 1/PEF)]} \qquad (A.2)$$

where:

C_{si} = soil concentration of contaminant i (mg/kg);

CF_3 = conversion factor (10^{-6} kg/mg);

CF_4 = conversion factor (365 d/yr);

BW = average body weight over the exposure period (kg);

AT = averaging time (yr);

SF_{oi} = oral slope factor for contaminant i ($[mg/kg\text{-}d]^{-1}$); and

SF_{ii} = inhalation slope factor for contaminant i ($[mg/kg\text{-}d]^{-1}$).

The concentrations corresponding to specified hazard quotients were calculated as follows:

$$C_{si} = \frac{THI \times BW \times AT \times CF_4}{(EF \times ED)\ [(1/RfD_{oi} \times CF_3 \times IR_s) + (1/RfD_{ii} \times IR_a \times ET \times 1/PEF)]} \qquad (A.3)$$

where:

THI = target hazard index (unitless);

RfD_{oi} = oral reference dose for contaminant i (mg/kg-d); and

RfD_{ii} = inhalation reference dose for contaminant i (mg/kg-d).

The toxicity values used in Equations A.2 and A.3 are discussed in Chapter 4 of the BA. Because the EPA continues to develop new and revise previous toxicity values as new information becomes available, the values presented in the BA were updated with information presented in EPA's *Integrated Risk Information System* (IRIS) (EPA 1993) and *Health Effects Assessment Summary Tables* (HEAST) (EPA 1992). For compounds for which a toxicity value had been withdrawn from IRIS or HEAST subsequent to its use in the BA, the value listed in the BA was used for the purpose of the preliminary calculations presented in this appendix.

The assumptions and intake parameters assumed for the recreational visitor are summarized in Table A.1. For this preliminary assessment, these values are the same as those used for the future recreational visitor assessed in the BA for the chemical plant area, as described in Section 3.4.2 of that document. The soil concentrations of radioactive contaminants that correspond to different levels of risk are shown in Table A.2; those for the chemical contaminants are shown in Tables A.3 and A.4.

A.2 GROUNDWATER

Under both current and future conditions, groundwater is not expected to represent a complete exposure pathway. That is, no receptors have been identified because groundwater in the alluvial aquifer in areas with elevated contaminant concentrations is not used

TABLE A.1 Exposure Scenario Assumptions and Intake Parameters

Parameter	Variable[a]	Current/Future Recreational Visitor	Groundwater User
Average body weight (kg)	BW	70	70
Inhalation rate (m^3/h)	IR_a	2.1	-[b]
Incidental ingestion of contaminated soil (mg/event)	IR_s	120	-
Water ingestion rate (L/d)	IR_w	-	2
Exposure time (h/event)	ET	4	-
Exposure frequency (events/yr or d/yr)	EF	20	350
Exposure duration (yr)	ED	30	30
Averaging time	AT		
Carcinogens (yr)		70	70
Noncarcinogens (yr)		30	30

[a] The listed variables are used in Equations A.1 through A.6.

[b] A hyphen indicates that the entry is not applicable.

TABLE A.2 Soil and Water Concentrations of Radionuclides Associated with Target Risk Levels[a]

Radionuclide	Soil Concentration (pCi/g) Relative to Risk		
	1×10^{-4}	1×10^{-5}	1×10^{-6}
Actinium-227	90	9.0	0.90
Lead-210	340	34	3.4
Protactinium-231	190	19	1.9
Radium-226[b]	14	1.4	0.14
Radium-228[c]	43	4.3	0.43
Thorium-230	4,200	420	42
Thorium-232	800	80	8.0
Uranium-235	650	65	6.5
Uranium-238[c]	2,400	240	24

Radionuclide	Water Concentration (pCi/L) Relative to Risk		
	1×10^{-4}	1×10^{-5}	1×10^{-6}
Actinium-227	0.53	0.053	0.0053
Lead-210	1.2	0.12	0.012
Protactinium-231	0.72	0.072	0.0072
Radium-226[b]	7.2	0.72	0.072
Radium-228[c]	6.2	0.62	0.062
Thorium-230	15	1.5	0.15
Thorium-232	2.8	0.28	0.028
Uranium-235	32	3.2	0.32
Uranium-238[c]	16	1.6	0.16

[a] Soil concentrations were calculated on the basis of the ingestion, inhalation, and external gamma pathways; water concentrations were calculated on the basis of the ingestion pathway.

[b] Radium-226 soil concentrations include the contribution from inhalation of radon-222. For groundwater concentrations, the contribution from radon as a result of volatilization would be insignificant compared to ingestion of radium-226 in drinking water.

[c] The risk from radium-228 includes the contribution from thorium-228, and the risk from uranium-238 includes the contribution from uranium-234.

TABLE A.3 Soil and Water Concentrations of Chemicals Associated with Target Risk Levels[a]

Chemical[b]	Soil Concentration (mg/kg) Relative to Risk 1×10^{-4}	1×10^{-5}	1×10^{-6}
Metals			
Arsenic	1,400	140	14
Beryllium	580	58	5.8
Cadmium	>500,000	>500,000	270,000
Chromium (VI)	>500,000	400,000	40,000
Nickel	>500,000	>500,000	>500,000
Nitroaromatic compounds			
2,4-DNT	3,700	370	37
2,6-DNT	3,700	370	37
TNT	83,000	8,300	830

Chemical[b]	Water Concentration (µg/L) Relative to Risk 1×10^{-4}	1×10^{-5}	1×10^{-6}
Metals			
Arsenic	4.7	0.47	0.047
Beryllium	2.0	0.20	0.020
Nitroaromatic compounds			
2,4-DNT	13	1.3	0.13
2,6-DNT	13	1.3	0.13
TNT	280	28	2.8

[a] Soil concentrations were calculated on the basis of the ingestion and inhalation pathways; water concentrations were calculated on the basis of the ingestion pathway.

[b] Listed are only those contaminants for which an oral or inhalation slope factor is available.

TABLE A.4 Soil and Water Concentrations of Chemicals Associated with Target Hazard Quotients[a]

Chemical	Soil Concentration (mg/kg) Relative to Hazard Quotient			
	1	0.5	0.3	0.1
Metals				
Aluminum	NQ[b]	NQ	NQ	NQ
Antimony	4,300	2,100	1,300	430
Arsenic	3,200	1,600	960	320
Barium	>500,000	370,000	220,000	74,000
Beryllium	53,000	27,000	16,000	5,300
Cadmium	11,000	5,300	3,200	1,100
Calcium	NQ	NQ	NQ	NQ
Chromium (III)	410,000	200,000	120,000	41,000
Chromium (VI)	47,000	24,000	14,000	4,700
Cobalt	NQ	NQ	NQ	NQ
Copper	430,000	210,000	130,000	43,000
Iron	NQ	NQ	NQ	NQ
Lead	NQ	NQ	NQ	NQ
Lithium	210,000	110,000	64,000	21,000
Magnesium	NQ	NQ	NQ	NQ
Manganese	>500,000	>500,000	310,000	105,000
Mercury	3,200	1,600	960	320
Molybdenum	53,000	27,000	16,000	5,300
Nickel	210,000	110,000	64,000	21,000
Potassium	NQ	NQ	NQ	NQ
Selenium	53,000	27,000	16,000	5,300
Silver	53,000	27,000	16,000	5,300
Sodium	NQ	NQ	NQ	NQ
Thallium	750	370	220	75
Uranium	32,000	16,000	9,600	3,200
Vanadium	75,000	37,000	22,000	7,500
Zinc	>500,000	>500,000	>500,000	320,000
Inorganic anions				
Chloride	NQ	NQ	NQ	NQ
Fluoride	>500,000	320,000	190,000	64,000
Nitrate (as N)[c]	120,000	60,000	36,000	12,000
Nitrite (as N)[c]	7,500	3,800	2,300	750
Sulfate	NQ	NQ	NQ	NQ
Nitroaromatic compounds				
DNB	1,100	530	320	110
2,4-DNT	21,000	11,000	6,400	2,100
2,6-DNT	43,000	21,000	13,000	4,300
NB	5,300	2,700	1,600	530
TNB	530	270	160	53
TNT	5,300	2,700	1,600	530

TABLE A.4 (Cont.)

Chemical	Water Concentration (µg/L) Relative to Hazard Quotient: 1	0.5	0.3	0.1
Metals				
Aluminum	NQ	NQ	NQ	NQ
Antimony	15	7.3	4.4	1.5
Arsenic	11	5.5	3.3	1.1
Barium	2,600	1,300	770	260
Beryllium	180	91	55	18
Cadmium	18	9.1	5.5	1.8
Calcium	NQ	NQ	NQ	NQ
Chromium (III)	37,000	18,000	11,000	3,700
Chromium (VI)	180	91	55	18
Cobalt	NQ	NQ	NQ	NQ
Copper	1,500	730	440	150
Iron	NQ	NQ	NQ	NQ
Lead	NQ	NQ	NQ	NQ
Lithium	730	370	220	73
Magnesium	NQ	NQ	NQ	NQ
Manganese	180	91	55	18
Mercury	11	5.5	3.3	1.1
Molybdenum	180	91	55	18
Nickel	730	370	220	73
Potassium	NQ	NQ	NQ	NQ
Selenium	180	91	55	18
Silver	180	91	55	18
Sodium	NQ	NQ	NQ	NQ
Thallium	2.6	1.3	0.77	0.26
Uranium	110	55	33	11
Vanadium	260	130	77	26
Zinc	11,000	5,500	3,300	1,100
Inorganic anions				
Chloride	NQ	NQ	NQ	NQ
Fluoride	2,200	1,100	660	220
Nitrate (as N)[d]	10,000	5,000	3,000	1,000
Nitrite (as N)[d]	1,000	500	300	100
Sulfate	NQ	NQ	NQ	NQ
Nitroaromatic compounds				
DNB	3.7	1.8	1.1	0.37
2,4-DNT	73	37	22	7.3
2,6-DNT	150	73	44	15
NB	18	9.1	5.5	1.8
TNB	1.8	0.91	0.55	0.18
TNT	18	9.1	5.5	1.8

See next page for footnotes.

TABLE A.4 (Cont.)

[a] Soil concentrations were calculated on the basis of the ingestion and inhalation pathways; water concentrations were calculated on the basis of the ingestion pathway.

[b] NQ indicates not quantified because a toxicity value was not available.

[c] Because the critical effect associated with exposure to nitrate and nitrite is an acute response (methemoglobinemia), the soil concentration has been derived on the basis of a single exposure of a 15-kg child ingesting 200 mg of soil, which is averaged over an exposure duration of one day. This results in a more conservative (lower) concentration than the value derived from the assumptions and intake parameters in Table A.1.

[d] The concentrations of 10,000 and 1,000 µg/L correspond to the MCLs for nitrate and nitrate (as nitrogen), derived for a 4-kg infant ingesting 0.64 L of water per day (EPA 1993). For nitrate, an additional uncertainty factor of 10 is applied because of the direct toxicity of this compound. These concentrations are more conservative than those derived from the assumptions and intake parameters in Table A.1.

for residential, agricultural, or other purposes (Section 3.1). However, the concentrations of radioactive and chemical contaminants in groundwater that correspond to different levels of risk and hazard quotient are estimated to help support development of the sampling plans. For this purpose, the receptor is assumed to be an individual ingesting 2 L/d of water.

Concentrations of radiological contaminants in groundwater corresponding to specified risk levels were calculated as follows:

$$R_{gwi} = \frac{TR}{IR_w \times EF \times ED \times DCF_{ing} \times \frac{6 \times 10^{-7}}{mrem}} \qquad (A.4)$$

where:

R_{gwi} = groundwater concentration of contaminant i (pCi/L); and

IR_w = groundwater ingestion rate (L/d).

For chemical contaminants, the concentrations corresponding to specified risk levels were calculated as follows:

$$C_{gwi} = \frac{TR \times BW \times AT \times CF_4 \times CF_5}{SF_{oi} \times IR_w \times EF \times ED} \qquad (A.5)$$

where:

C_{gwi} = groundwater concentration of contaminant i (μg/L); and

CF_5 = conversion faction (10^3 μg/mg).

The concentrations corresponding to specified levels of hazard quotient were calculated as follows:

$$C_{gwi} = \frac{THI \times RfD_{oi} \times BW \times AT \times CF_4 \times CF_5}{IR_w \times EF \times ED} \qquad (A.6)$$

The assumptions and intake parameters used for the assessment of this pathway are summarized in Table A.1, and the toxicity values are discussed in Section A.1. The groundwater concentrations of radioactive and chemical contaminants that correspond to different levels of risk and hazard index are shown in Tables A.2, A.3, and A.4.

A.3 REFERENCES

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